B. SUNDARASIVARAO* & NAZMA*: Variation in length of vessel-elements and libriform fibres within one tree, *Aesculus hippocastanum* L.

B. スンダラシバラオ*・ナズマ*: セイヨウトチノキの一樹中における導管細胞と繊維細胞の長さの変異

Ever since Sanio (1872) formulated the criteria of variation in length of tracheids from his studies on scots pine (*Pinus sylvestris*), work done subsequently was mostly confined to the study of tracheid length variation in soft woods because of its practical significance in paper and pulp industry, and in its relationship with the properties of wood (Shepard & Bailey, 1914; Bailey, 1920; Chalk, 1930; Chalk & Ortiz, 1961). In the recent years variation in length of vessel-elements and libriform fibres has been studied in a few angiosperms by Bisset & Dadswell (1949); Bisset, Dadswell and Amos (1950); Chalk, Marstrand and Walsh (1955); Sundarasivarao (1959); Dinwoodie (1960); Swamy, Parameswaran and Govindarajulu (1960); Sundarasivarao and Prakasarao (1972); Sundarasivarao *et al.* (1973). However, information regarding variation in length of these elements in individual angiosperm trees appears to be inadequate and in view of the comparative lack of definite information, an attempt is made in the present investigation to bring out the nature of variation in length of vessel-elements and libriform fibres in *Aesculus hippocastanum* L., along the following lines:

i) Variation in length of these elements in successive growth rings from pith outwards at different levels in the bole.

ii) Variation in length of these elements in specific growth rings at different heights from base upward in the bole.

iii) Variation in length of these elements within one ring between the first formed early wood and the last formed late wood at one level in the bole.

Material and Methods Material used in this investigation is a horse chestnut (*Aesculus hippocastanum* L.) collected by the senior author from

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the grounds of Royal Holloway College, University of London, U.K. The approximate age of the tree is 56 years. Four transverse discs each of three inches thick were taken at 8, 13, 17 and 21 feet from the base of the bole and these discs are referred in this work as D_{I}, D_{II}, D_{III} and D_{IV}.

In each of these discs measurements are taken from temporary glycerine mounts of the macerated wood from each of the first six rings, then from every alternate ring upto the sixteenth and afterwards from every fourth ring from pith outwards along one radius, due south, to avoid directional effect, if any. Macerations were made according to the technique outlined by Jeffrey (1917). Fifty measurements were taken from each of the samples conforming to the suggestions of Rendle and Clarke (1934) and Chalk and

Table 1. Variation in length of libriform fibres in *Aesculus hippocastanum*.

	D_{I}		D_{II}		D_{III}		D_{IV}	
Growth Ring	mm.	Std. Dvn.	mm.	Std. Dvn.	mm.	Std. Dvn.	mm.	Std. Dvn.
1.	.401	± .103	.498	± .078	.517	± .102	.429	± .086
2.	.476	± .103	.559	± .068	.521	± .067	.474	± .084
3.	.475	± .091	.621	± .064	.558	± .050	.536	± .095
4.	.512	± .167	.607	± .070	.609	± .084	.553	± .112
5.	.546	± .120	.629	± .089	.662	± .081	.582	± .098
6.	.587	± .115	.685	± .087	.672	± .081	.620	± .072
8.	.670	± .078	.669	± .094	.672	± .089	.602	± .084
10.	.636	± .090	.700	± .104	.657	± .075	.608	± .095
12.	.616	± .100	.676	± .097	.642	± .067	.613	± .067
14.	.622	± .106	.721	± .082	.688	± .069	.628	± .069
16.	.667	± .095	.710	± .086	.688	± .081	.647	± .070
20.	.672	± .086	.737	± .042	.674	± .079	.699	± .084
24.	.694	± .165	.703	± .054	.705	± .090	.686	± .090
28.	.726	± .146	.723	± .078	.713	± .108	.694	± .095
32.	.732	± .054	.713	± .087	.691	± .079	.712	± .096
36.	.718	± .084	.745	± .062	.709	± .086	.720	± .081
40.	.689	± .075	.736	± .075	.700	± .084	.714	± .090
44.	.700	± .079	.761	± .081	.714	± .078	.724	± .084
48.	.726	± .146	.762	± .073	.708	± .070	....	
52.	.700	± .079	.782	± .067	....		....	
56.	.718	± .084	....		....		....	

Each figure in the table represents the mean value in millimetres of fifty measurements with the corresponding standard deviation.

Chattaway (1935) with the help of an ocular micrometer. The mean lengths of these elements are expressed in millimetres with standard deviation against each in Tables 1-3. Standard deviation is calculated according to the formula $\sqrt{\frac{\sum X^2 - \sum^2 X}{n}}$ where $\sum X^2$ is the sum of squares of each of the values, $\sum^2 X$ is the square of the sum of the values and 'n' is the number of observations. Variation in length of these elements between the early and late wood of one ring was carried out according to the procedure outlined by Bisset and Dadswell (1950).

Results and Discussion Results obtained in the study of variation in length of the libriform fibres and vessel-elements in successive growth rings from pith outwards in the present investigation are presented in Table 1,

Table 1a. Variation in length of vessel-elements in *Aesculus hippocastanum*.

	D_{I}		D_{II}		D_{III}		D_{IV}	
Growth Ring	mm.	Std. Dvn.	mm.	Std. Dvn.	mm.	Std. Dvn.	mm.	Std. Dvn.
1.	.273	± .072	.332	± .062	.354	± .048	.324	± .064
2.	.313	± .030	.386	± .054	.373	± .047	.349	± .042
3.	.328	± .055	.406	± .070	.384	± .046	.392	± .058
4.	.341	± .091	.419	± .047	.408	± .089	.401	± .056
5.	.357	± .062	.438	± .064	.447	± .047	.416	± .060
6.	.385	± .061	.448	± .070	.457	± .052	.442	± .062
8.	.431	± .064	.453	± .050	.444	± .062	.425	± .073
10.	.392	± .055	.476	± .062	.441	± .064	.451	± .058
12.	.419	± .069	.461	± .079	.441	± .042	.438	± .065
14.	.411	± .069	.474	± .067	.445	± .064	.432	± .062
16.	.402	± .079	.470	± .056	.455	± .047	.440	± .051
20.	.431	± .056	.476	± .065	.464	± .054	.485	± .078
24.	.457	± .086	.469	± .026	.471	± .082	.483	± .047
28.	.441	± .076	.476	± .070	.464	± .054	.473	± .086
32.	.478	± .078	.493	± .086	.469	± .123	.494	± .003
36.	.458	± .058	.499	± .096	.469	± .042	.482	± .052
40.	.454	± .117	.510	± .070	.484	± .078	.481	± .072
44.	.450	± .060	.509	± .075	.484	± .060	.498	± .060
48.	.446	± .062	.509	± .058	.467	± .015	....	
52.	.430	± .037	.532	± .062	....		....	
56.	.443	± .058	....		....		....	

Each figure in the table represents the mean value in millimetres of fifty measurements with the corresponding standard deviation.

Table 2. Variation in length of vessel-elements and libriform fibres in *Aesculus hippocastanum* in specific growth rings from base upwards in the bole.

Growth Ring	DI VE	DI Fib	DII VE	DII Fib	DIII VE	DIII Fib	DIV VE	DIV Fib
1928	.441	.726	.469	.703	.464	.674	.440	.647
1940	.454	.689	.499	.745	.469	.691	.473	.696
1952	.430	.700	.509	.762	.484	.714	.491	.714

VE=Vessel-elements. Fib=Libriform fibres.

Table 3. Variation in vessel-element and libriform fibre length within one growth ring in *Aesculus hippocastanum*.

Growth Ring	Vessel Elements	Libriform Fibres	
1923	.482	.747	Late wood
	.474	.640	Early wood
	.476	.664	
	.488	.695	
1924	.499	.704	
	.509	.722	
	.512	.750	
	.523	.765	
	.496	.732	Late wood
1925	.491	.643	Early wood

Each figure in the tables 2 and 3 represents the mean value in millimetres of fifty measurements.

where each figure represents mean length in millimetres with the corresponding standard deviation. From the data it is evident that there is an initial rapid increase in length of the vessel-elements and libriform fibres upto the first ten growth rings, after which the length of these elements fluctuated in the later growth rings with an overall increase in length (Fig. 1). This initial rapid increase in length of these elements may be attributed to the ever increasing fusiform initials of the vascular cambium which, according to Bailey (1923), will increase in length for about 60 years in dicotyledons. Similar trend was reported by many of the recent workers, Bisset and Dadswell (1949), Sundarasivarao (1959), Sundarasivarao and Prakasarao (1972) and Sundarasivarao *et al.* (1973). The results also indicate that the

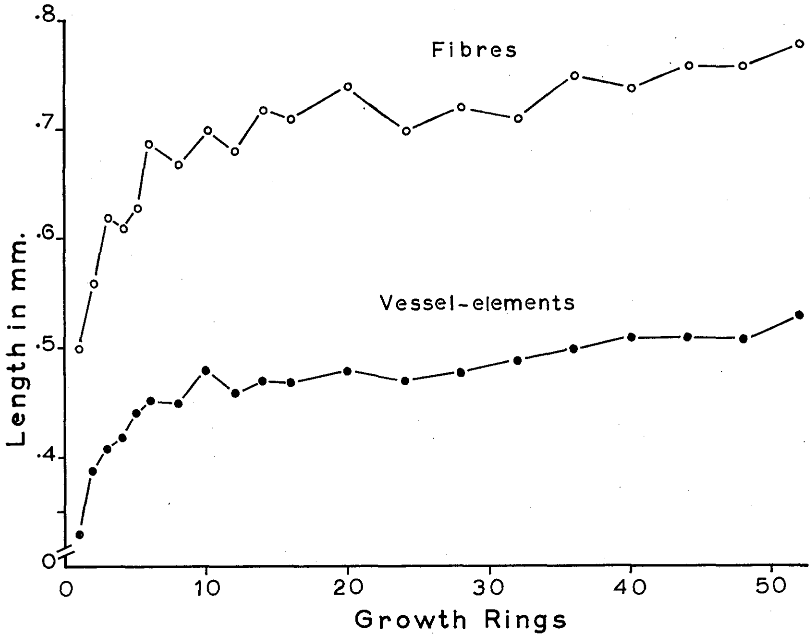

Fig. 1. *Aesculus hippocastanum.* Variation in length of vessel-elements and libriform fibres in successive growth rings from pith outwards (DII).

maximum length attained by these two types of elements varied with the position of the growth ring with reference to the pith at any one level and with the height in the bole. Neither the libriform fibres nor the vessel-elements attained a constant length in the later growth rings at any given level in the bole. This may be due to the fact that the wood lies, perhaps, still in that period of increasing activity. It is also noted that the increase in length of these elements is more gradual in the successive growth rings in the discs taken nearer the ground, than those higher up in the bole showing a positive correlation with the size of the fusiform initials which are longer higher up in the bole at any particular distance from the pith. Kribs (1928) in *Pinus banksiana*, Bisset and Dadswell (1949) in *Eucalyptus regnans*, Sundarasivarao (1959) in oak, sycamore, *Robinia* and beech have all indicated a high correlation between the age of the growth ring from the pith and length of the vertical elements of the secondary xylem at higher levels of the tree.

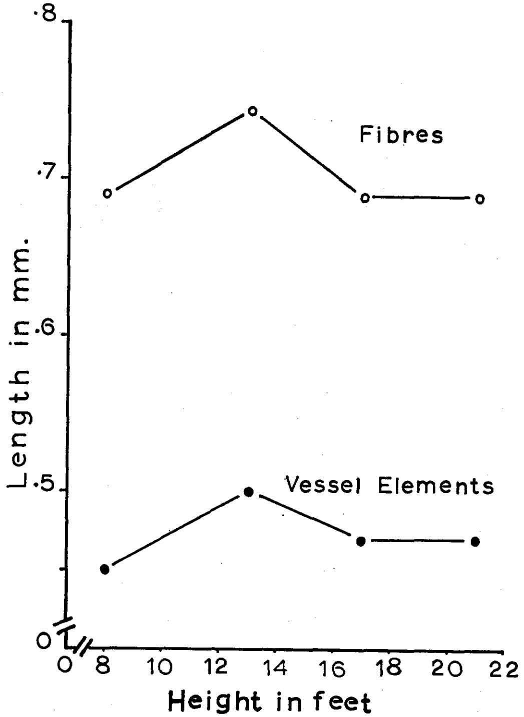

Fig. 2. *Aesculus hippocastanum.* Variation in length of vessel-elements and libriform fibres in a specific growth ring (1941).

Results obtained in the study of variation of these elements in specific growth rings from the base upwards in the bole are represented in Fig. 2. It is found that there is an increase in length of these elements in a given growth ring from base upwards to a certain height after which the length of these elements decreased. It is further noted that the maximum length attained by these elements is at about a height of thirteen feet in the bole. These observations are in conformity with the fiindings of Bisset and Dadswell (1950), Sundarasivarao (1959) and Sundarasivarao *et al.* (1973).

In the study of variation in length of these elements from the early wood and late wood of one growth ring, data was also taken from the late wood of the previous growth ring and the early wood of the succeeding growth ring to assess the trend of variation at the transition from late

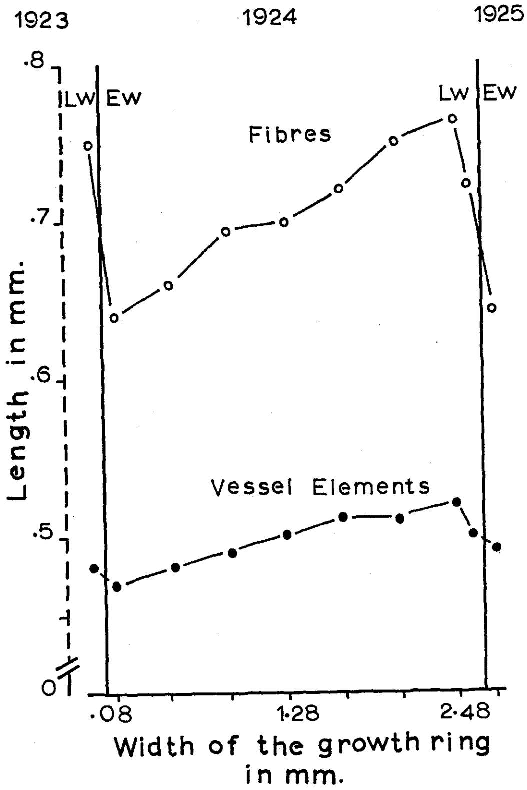

Fig. 3 *Aesculus hippocastanum.* Variation in length of vessel-elements and libriform fibres within one growth ring.

wood of one ring to the early wood of the succeeding growth ring. The results indicated that these elements are shorter in the first formed early wood than those of the last formed late wood of the growth ring (Fig. 3). Further the increase in length of these elements is gradual from the early wood of the ring to the late wood with the maximum length being attained in the last formed late wood. In the transition from the late wood of one growth ring to the early wood of succeeding ring an abrupt decrease in length of these elements is noted. The results obtained on this aspect are in agreement with the type of variation reported by Bisset, Dadswell and Amos (1950), Sundarasivarao (1959), Swamy, Parameswaran and Govindarajulu

(1960) and Sundarasivarao *et al.* (1973). The difference in length of the libriform fibres between the early and late wood of a ring may be due to the strong intrusive growth taking place at the both ends of the derivatives of the vascular cambium during differentiation. However, the distinct difference in length of the vessel-elements within a ring between the early and the late wood may be due to varying degrees of distension and also to the increasing length of the fusiform initials between the beginning and end of a growth ring. The sudden decrease in length of these elements at the region of transition from last formed late wood of one growth ring to the first formed early wood of the succeeding ring is also in agreement with the observations of Bisset and Dadswell and Amos (1950), Sundarasivarao (1959), Swamy *et al.* (1960) and Sundarasivarao *et al.* (1973).

Summary. Variation in length of vessel-elements and libriform fibres is studied in *Aesculus hippocastanum* L., in successive growth rings at four different levels in the bole, in a specific ring from base upwards and between the early and late wood of one ring. These elements show an initial rapid increase in length at any one level, which is gradually nearer the base than higher up. In a specific ring these elements increase in length upto certain height. Early wood elements are shorter than those of the late wood in a specific ring with an abrupt fall in length at the transitional region from late wood to early wood.

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セイヨウトチノキ（マロニエ）*Aesculus hippocastanum* L. の一個の樹幹の木部における導管細胞と繊維細胞について，幹における位置および季節によるそれらの長さの差違を研究した。これは次の3種に分けて測定した。i) 内部と外部との年輪における差異，ii) 同一の年輪について，幹の基部から上方に至る間の差異，iii) 一定地上高の一個の年輪について，春材と夏材における差異。結果は表1, 2に示した。

○旧別子の鉱山あとに出現したシダ（山中二男）Tsugiwo YAMANAKA: Warm-temperate ferns luxuriant at an unworked copper mine in the cool-temperate zone

わが国最大の金属鉱山の一つに数えられる別子銅山は，さきごろ閉山したが別子の発展のかげには大きな環境の汚染と破壊をともなっていた。それは，植生にも端的にあらわれていて，極相のすがたを残す森林は，別子の周辺には無いといってもよく，